

APPLICATION UNDER UNITED STATES PATENT LAWS

Atty. Dkt. No. PW 316312
(M#)

Invention: INTEGRATED OPTICS COUPLING ELEMENT COMPRISING A GRATING PRODUCED IN A CLADDING AND METHOD FOR MAKING SAME

Inventor (s): Christophe MARTINEZ

Pillsbury Winthrop Shaw Pittman LLP
Intellectual Property Group
P.O. Box 10500
McLean, VA 22102-4859

Attorneys
Telephone: (703) 770-7900

This is a:

- Provisional Application
- Regular Utility Application
- Continuing Application
 - The contents of the parent are incorporated by reference
- PCT National Phase Application
- Design Application
- Reissue Application
- Plant Application
- Substitute Specification
 - Sub. Spec Filed _____
 - in App. No. _____
- Marked up Specification re
Sub. Spec. filed March 14, 2006
In App. No 10/538,139

SPECIFICATION

INTEGRATED OPTICS COUPLING ELEMENT COMPRISING A GRATING
CREATED IN A CLADDING AND ITS FABRICATION METHOD

TECHNICAL FIELD

The invention relates to an integrated optics coupling element comprising an optical grating created in a cladding
5 ~~as well as its fabrication, and to a method for manufacturing the same.~~

10 The ~~Embodiments of the invention has have~~ applications in all fields ~~requiring, in which~~ a coupling between an optical cladding and a guide core or vice versa ~~is desired,~~ and in particular in the field of spectral filtering. ~~It particularly applies to the creation of Embodiments of the invention may be used to create~~ gain flatteners for optical amplifiers ~~used for example in the telecommunications field or even for creating to create~~ linear response filters whose ~~wave length wavelength~~ is on a spectral band defined for the spectral recognition, in particular for the measurement of spectral offsets from a power variation for example in the field of sensors.

20 STATE OF THE PRIOR ART

BACKGROUND

Currently, the creation of ~~grating~~ Grating coupling elements may be created in optical ~~fiber~~ fiber claddings ~~is known~~. In this field, the optical cladding of a ~~fiber~~ fiber 25 traditionally surrounds the ~~fiber~~ fiber core and has a refractive index lower than that of the core to allow the propagation of a light wave in the core. Conjointly, the optical cladding permits the mechanical support of the core. The ~~fiber~~ fiber core ~~cannot~~ may not exist without the cladding.

30 Furthermore, the grating created in the ~~fiber~~ fiber permits one or more guided modes to be coupled in the core of

a fibrefiber to one or more fibrefiber cladding modes or vice versa.

The document (1) whose reference is provided at the end of the description C.Y. Lin and L.A. Wang, "Loss-tunable long period fibre grating made from etched corrugation structure," Electron. Lett., 35 (21), (1999), pp 1872-1873, illustrates a grating coupling element obtained by etching the cladding. However, the creation principlemanufacturing process of this type of grating ismay be complex. For example, among others 10 it requiresit may require the cladding to be etched, which makesmay render the fibrefiber fragile.

Figure 1 shows a perspective view of an example of a coupling element in an optical fibrefiber. The fibrefiber 1 comprises a core 3 (shown in dotted lines) and a cladding 5; 15 the latter has been etched for a period Λ to create a grating R having a period Λ . We can clearly see in this figure that the The mechanical rigidity of the fibre isfiber may be modified by the etching 7 created in the cladding 5.

In addition to the mechanical difficulties Furthermore, 20 as the core of a fibre cannotmay not exist without the optical cladding, this dependence restrictsmay restrict the possibilities of modifying the parameters of the cladding, and the gratings and, as well as solutions for the design, architecture and integration of the coupling elements in 25 complex systems.

DESCRIPTION OF THE INVENTION

SUMMARY

The purpose of this invention is to propose an integrated 30 opticsEmbodiments of the invention have applications in all fields, in which a coupling between an optical cladding and a guide core or vice versa is desired, and in particular in the field of spectral filtering. Embodiments of the invention

5 may be used to create gain flatteners for optical amplifiers in the telecommunications field or to create linear response filters whose wavelength is on a spectral band defined for the spectral recognition, in particular for the measurement of spectral offsets from a power variation for example in the field of sensors.

10 Embodiments of the invention include a coupling element comprising an optical grating created in a cladding by modulation of the cladding structure as well as its creation process. The use of an integrated optics cladding permits the difficulties of the prior art to be overcome by offering in particular more flexibility in the fabrication of Embodiments of the invention provide a flexible fabrication process for defining the modulation of the cladding structure and by offering an element that is not fragile.

15 One purposeEmbodiments of the invention is also to proposeinclude a coupling element comprising a grating included in a cladding that is independent of the guide core to which it is associated. By independence of the core and the cladding, it is meant that ~~ean~~the core and the cladding may exist in a substrate independently from one another. In other words, the core ~~ean~~may exist without the cladding and the cladding ~~ean~~may exist without the core.

20 More precisely, the integrated optics coupling element of the invention comprises in a substrate an optical guide core, an optical cladding independent of the core and surrounding at least one portion of the core in a zone of the substrate called the zone of interaction, in which the cladding has at least in the zone of interaction a modulation of its structure so as to form a coupling grating between the guide core and the optical cladding, in which the refractive index of the cladding is different from the refractive index of the substrate and lower than the refractive index of the core, at

least in the part of the cladding next to the core in the zone of interaction.

By surrounding, it is meant that the fundamental mode profile of the guide core has a maximum that is included in the index profile of the cladding. In this way, the fundamental mode profile of the core may be completely or partially included in the cladding index profile, which results at structural level in a core positioned anywhere ~~at all~~ in the cladding including at its edge in which case the core may be partially outside of the cladding.

The zone of interaction corresponding to a grating coupling zone in a substrate ~~will~~may also be ~~called~~termed "artificial cladding grating" (ACG). ~~In fact,~~ in this zone, the cladding is artificially created in the substrate and independently of the core.

The grating formed from the cladding is ~~capable of~~ couplingconfigured to couple the one or more core modes to one or more cladding modes or vice versa.

In a first-~~advantageous~~ embodiment, the modulation of the cladding structure is a modulation of its section and preferably of its width, considered in a direction perpendicular to the direction of propagation of the modes.

In a second ~~advantageous~~-embodiment, which may be combined with the first ~~mode~~embodiment, the modulation of the cladding structure is a modulation of the position of the cladding with respect to the core.

The fabrication of the integrated optics cladding ~~permits~~ itmay be obtained by a modification of the refractive index of the substrate, in particular by implantation or ionic exchange. Consequently, the modulation of the cladding structure ~~can~~may be obtained without etching or fusion-as-in-the-prior-art.

The solution of the invention therefore offers advantagesbenefits such as the simplicity of creation and sturdiness of the coupling element.

Furthermore, the independence between the core and the 5 cladding allows a higher number of combinations to be created by varying not justonly the size of the cladding but also the position of the core in the cladding. The independence of the cladding and the core also permits easy integration of the coupling element of the invention into a complex architecture.

10 The grating in accordance with embodiments of the invention may comprise one or more elementary gratings, each elementary grating creating an elementary zone of interaction.

The effective index n_{eff}^0 of the mode spreadingpropagating in the core depends on the surrounding medium. According to 15 the cladding index and its extent in the substrate, the value of the effective index of the core mode changes. In this way, by periodically or pseudo-periodically modulating the cladding structure, this variation canmay be transmitted to the effective index value of the core, and thus, may induce 20 a coupling between the one or more core modes and the one or more cladding modes and in this way create a grating.

The use of the modulation of the cladding structure is particularly advantageousbeneficial to create a grating.—In fact Indeed, one of the factors restrictingthat may restrict 25 the parameter adjustment of the coupling coefficient desired for the grating is provided, in the case of masks being used, by the size of the minimum pattern of the mask lithography permitting the gratings to be created. As this limit is identical for the core and the cladding, it canwill be easily 30 understoodappreciated that it is easier to obtain slight variations on n_{eff}^0 by varying the structure of the cladding. Consequently, grating type component applications, in particular apodisedapodized, are thus favouredfavored.

In a first embodiment, the grating formed by the modulation of the cladding structure is an apodisedapodized grating.

5 In a second embodiment, the grating formed by the modulation of the cladding structure is a chirped grating.

As we have already seen, the The cladding structure hasmay have an influence on the effective index of the core mode. Whereas However, the value of the resonance wave wavelength of the ACG for a coupling from the 0 mode of 10 the core to the j mode of the cladding depends on the effective index values as shown by the following equation:

$$\lambda_{0j} = \Lambda \times \left(n_{\text{eff}}^0 - n_{\text{eff}}^j \right) \quad (1)$$

15 Λ is the period of the grating.

A variation in the size of the cladding and/or de its position with respect to the core therefore permits the value of λ_{0j} to be accordedchanged.

20 Coupling the core for example to the cladding (the same logic canapproach may be used for coupling the cladding to the core), results in a transfer of energy between the guided mode of the core and that of the cladding for wave wavelengths of λ_{0j} . The energy coupled in the cladding modes is then guided in the cladding generally with losses.

25 The modification of λ_{0j} therefore passes by adjustment effIt is desirable to adjust the parameters of Λ and/or the distribution of the effective indices of the various modes to modify λ_{0j} .

30 The efficiency of the coupling between the modes dependsmay depend on the length of the grating and the coupling coefficient K_{0j} between the 0 and j modes. This coefficient is provided by the spatial recovery integral of the 0 and j

modes, weighted by the index profile induced by the grating. We therefore have a relationship of the type:

$$K_{OJ} \propto \iint \xi_0 \cdot \xi_j^* \cdot \Delta n \cdot ds \quad (2)$$

5

where:

- ξ_0 and ξ_j are the transversal profiles of the 0 and j modes and ξ_j^* is the complex conjugate of ξ_j

10 - Δn is the amplitude of the effective index modulation induced by the grating in a plane perpendicular to the direction of propagation of the wave,

- ds is an integration element in a plane perpendicular to the axis of propagation of the wave.

15 The modification of K_{OJ} is obtained by varying the profile of the modes and/or the index profile induced by the grating, ~~in other words for example~~, by varying the opto-geometrical characteristics of the cladding and/or of the core (dimensions, index level, etc.) and/or the characteristics of the grating (Δn , position of the grating 20 with respect to the core and to the cladding, etc.).

25 ~~As concerns a~~ With respect to the cladding, the larger its dimensions and index level, the more cladding modes will be allowed to spread propagate and the more spectral filtering bands will be possible. This may be an advantage a benefit if seeking multiple filtering is desired or to have if more flexibility in the selection of a filtering mode is desired.

~~If seeking~~ In order to limit the number de cladding modes that can be coupled, it is of interest on the contrary to reduce the opto-geometrical dimensions of the cladding.

30 ~~As concerns~~ With respect to the core, its dimensions and index level may determine the characteristics of the mode, which spreads propagate. Furthermore, the more the index

5 differences between the core, the cladding and the substrate are high, the more there will be potentially a chance of having couplings for low grating periods as shown by the equation (1) (at a ~~wave length~~wavelength of given resonance, the period is inversely related to the index difference between the guided mode of the core and the cladding mode).

10 By modifying the position of the core, the grating and the cladding, different couplings ~~can~~may be generated. ~~In fact, we can clearly see from the~~ Indeed, equation (2) shows that the coupling force/coupling efficiency depends on the relative position in the plane transversal to the axis of propagation of the profiles of the cladding mode, of the guided mode of the core and the grating.

15 In particular, from the equation (2), it can easily be shown that a decentration δx of the core with respect to the cladding ~~permits K to be increased.~~ increases K.

Also, in one embodiment of the invention the core of the coupling element is totally or partially decentred with respect to the cladding.

20 ~~By spectral~~Spectral band it is meant ~~refers to~~ a band with a set of ~~wave length~~wavelengths whose central ~~wave length~~wavelength and ~~band width~~bandwidth are determined, given that a light wave ~~can~~may comprise one or more several spectral bands.

25 In embodiments of the invention, the cladding and the core exist independently from one another in the substrate, ~~which is not the case in the prior art.~~ This independence permits more flexibility in the creation of the coupling element. In particular, the core ~~can~~may no longer be situated in the cladding outside of the zone of interaction but solely in the substrate which permits the optical isolation of the core. In this way, the cladding may only ~~influence~~influence the propagation of a light wave in the associated guide core in

the part surrounding the core and the cladding ~~can~~may guide or transport light waves independently of the core.

The substrate may ~~of course~~ be made using a single material or by ~~the~~ superposition of several layers of materials.

5 In this case, the refractive index of the cladding is different from the refractive index of the substrate at least in the layers next to the cladding.

~~Advantageously~~In an embodiment, each elementary cladding has a refractive index higher than that of the substrate.

10 In embodiments of the invention, the guide may be a planar guide when the light is confined in a plane containing the direction of propagation of the light or a micro guide, when the light is confined in two directions transversal to the direction of propagation of the light.

15 The grating may be formed by an elementary grating or a set of elementary gratings in series. The characteristics of the zone of interaction of the coupling element are such that they permit the desired light spectrum to be obtained at the output of this element.

20 In one preferred embodiment, the cladding and/or the guide core, may be created by any type of technique which permits the refractive index of the substrate to be modified. In particular ~~we can mention~~the ion exchange techniques, ionic implantation and/or radiation, for example, by laser 25 exposure or laser photo inscription or even the ~~depositing of layers, or a layer deposition process may be used.~~

The technology of ion exchange in glass is particularly interesting but other substrates apart from glass ~~may of course~~ be used such as for example crystalline substrates of the KTP, 30 LiNbO₃ or even the LiTaO₃ type.

When the cladding is created from a mask, the grating pattern ~~is advantageously~~may be obtained by the same mask.

The Embodiments of the invention also ~~relates~~relate to a method for fabricating an integrated optics coupling element as previously defined, the cladding and the guide core being respectively created by modification of the refractive index 5 of the substrate so that at least part of the cladding next to the core and at least in the zone of interaction, the refractive index of the cladding is different from the refractive index of the substrate and lower than the refractive index of the core and so that the cladding in the zone of 10 interaction comprises a modulation of its structure capable of forming the grating.

In one preferred embodiment, the method of the invention comprises the following ~~steps~~acts:

- a) introduction of a first ionic species in the 15 substrate to permit the optical cladding to be obtained after ~~step~~act c),
- b) introduction of a second ionic species in the substrate to permit the guide core to be obtained after ~~step~~act c),
- 20 c) burying of the ions introduced in ~~steps~~acts a) and b) to obtain the cladding and the guide core,

The It will be appreciated that the order of the ~~steps~~acts may ~~of course~~ be inverted.

The first and/or the second ionic species ~~is/are~~ 25 ~~advantageously~~may be introduced by an ionic exchange, or by ionic implantation.

The first and second ionic species may be the same or different.

The introduction of the first ionic species and/or the 30 second ionic species may be made with the application of an electrical field.

In the case of an ionic exchange, it is desirable that the substrate ~~must~~ contain ionic species capable of being exchanged.

According to one preferred embodiment, the substrate is 5 made of glass and contains Na^+ ions introduced beforehand, the first and second ionic species are Ag^+ and/or K^+ ions.

In a first embodiment, step a) comprises the creation of a first mask comprising a pattern capable of creating the cladding, the first ionic species being introduced through 10 this first mask and step b) comprises the elimination of the first mask and the creation of a second mask comprising a pattern capable of creating the core, the second ionic species being introduced through this second mask.

~~The~~ In an embodiment, the first mask comprises a pattern 15 whose structure is modulated to obtain the desired structure modulation of the cladding permitting the grating to be formed.

~~In one variant of the another~~ embodiment, the first mask comprises a uniform pattern, in which the modulation of the cladding structure is obtained after elimination of the first 20 mask by ~~localised~~local heating of the cladding, by any known means.

In a second embodiment, step a) comprises the creation of a mask comprising a pattern ~~capable of creating~~configured to create the cladding and the core, the introduction of the 25 first and the second ionic species of step a) and b) being carried out through this mask; the modulation of the cladding structure ~~is advantageously~~may be obtained in this case by ~~localised~~local heating.

The masks used in the invention ~~are for example~~may be made 30 of ~~aluminium~~aluminum, chrome, alumina or dielectric material.

In a first embodiment ~~of step, in act~~ c), the first ionic species is buried at least partially prior to step b) and

the second ionic species is buried at least partially after ~~step~~act b).

According to a second embodiment ~~of step, in act~~ c), the first ionic species and the second ionic species are buried 5 simultaneously after ~~step~~act b).

According to a third embodiment ~~of step, in act~~ c), the burying comprises the depositing of at least one layer of refractive material, whose index ~~is advantageously~~may be lower than that of the cladding, on the surface of the substrate.

10 This mode may ~~of course~~ be combined with the two previous modes.

~~Advantageously~~In an embodiment, at least part of the burying is carried out with the application of an electrical field.

15 ~~Generally~~In an embodiment, prior to burying with an electrical field and/or the depositing of a layer, the process of the invention may comprise among others burying by re-diffusion in an ionic bath.

20 ~~This step of~~The re-diffusion may be carried out partially prior to ~~step~~act b) to re-diffuse the ions of the first ionic species and partially after ~~step~~act b) to re-diffuse the ions of the first and second ionic species. This re-diffusion-step may also be carried out completely after ~~step~~act b) to re-diffuse the ions of the first and second ionic species.

25 By way of example, this re-diffusion is obtained by plunging the substrate in a bath containing the same ionic species as that previously contained in the substrate.

30 Other characteristics and ~~advantages~~benefits of the invention will ~~become clearer from~~be discussed in the following description, ~~in~~in reference to the figures of the appended drawings. This description is given by way of illustration and is not restrictive.

BRIEF DESCRIPTION OF THE FIGURES DRAWINGS

Figure 1 already described, schematically shows diagrammatically an optical fiber comprising a grating created by etched grooves in the cladding,

5 figure Figure 2 shows diagrammatically in a schematic cross section, a first example of an embodiment of a coupling element in accordance with an embodiment of the invention,

figure Figure 3 shows diagrammatically in a schematic cross section, a variant of the of a coupling element in accordance

10 with an embodiment of the coupling element of figure 2, invention,

figure Figure 4 shows diagrammatically in a schematic cross section, a second example of an embodiment of a coupling element in accordance with an embodiment of the invention,

15 figure Figure 5 shows diagrammatically in a schematic cross section, a third example of an embodiment of a coupling element in accordance with an embodiment of the invention,

figure Figure 6 shows diagrammatically in a schematic cross section, a fourth example of an embodiment of a coupling element in accordance with an embodiment of the invention,

20 figure Figure 7 shows diagrammatically in a schematic cross section, an example of an application of the coupling element in accordance with an embodiment of the invention,

figures 8a to 8d show diagrammatically an example of an embodiment of the invention,

figures 9a and 9b show diagrammatically a variant of an embodiment of the invention, and

25 Figures 8a to 8d schematically show a method for manufacturing the coupling element in accordance with an embodiment of the invention,

Figures 9a and 9b schematically show a method for manufacturing the coupling element in accordance with an embodiment of the invention, and

~~figures~~ Figures 10a and 10b show diagrammatically examples of embodiments of the mask permitting patterns configured to define a cladding with having a modulated section modulation to be obtained.

5

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figures 2 to 7 show examples of embodiments of coupling elements in cross sections containing the direction of propagation x of the light waves in the core of the ~~said~~ element.

10 In ~~order~~ Figures 2 to simplify things, 7, the direction of propagation is shown contained in a same plane, it of course being understood. However, it will be appreciated that the element core may be buried at variable depths.

15 Figure 2 shows diagrammatically in a cross section, a first example of an embodiment of a coupling element in accordance with an embodiment of the invention.

20 This figure shows a substrate 11 in which including a cladding 13 and a core 12 are created. 12. The cladding 13 comprises a modulation of its width (considered in a direction y perpendicular to the direction of propagation x) in a zone I of the cladding, called which may be referred to as the zone of interaction. This width modulation creates a grating R with a pitch Λ capable of coupling configured to couple one or more core propagation modes to one or more cladding propagation modes or vice versa.

25 The core exists independently of the cladding. It has a constant section and in this example traverses the cladding and in particular the zone of interaction I.

30 In this example, the cladding has a section which varies sinusoidally with the pitch Λ . To simplify this figure, only four grating periods have been shown.

Figure 3 shows diagrammatically in a cross section, a variant of an embodiment of the coupling element of ~~figure~~ Figure 2. This element differs from that of ~~figure~~ Figure

2 by a core 14 which is ~~decentred~~decentered with respect to the axis of symmetry of the cladding in the direction x. ~~This variant permits~~ In this embodiment, a parameter element related to be added concerning the coupling coefficient 5 between the cladding and the core by the grating may be added.

Figure 4 shows diagrammatically in a cross section, a second example of an embodiment of a coupling element of the invention.

As in figure 2, this coupling element comprises in a 10 substrate 11, a core 12 which traverses the cladding 15 in its axis of symmetry considered in the direction x.

The cladding also has a modulation of section, creating a grating R. In this example, the grating is an ~~apodised~~apodized grating. ~~In fact~~ Indeed, the 15 pseudo-sinusoidal pattern of the grating is not constant and decreases at both ends. ~~This is the principle of apodisation that means that~~ In an apodized grating, the disruption which generates the coupling phenomenon in the zone of interaction I appears and progressively disappears along the propagation 20 of the one or more modes.

The variation of section of the cladding induces disruptions whose consequences may be much less important than in the case of the variation of the core section (in particular due to the dimensions of the cladding). The modulation of the 25 section of the cladding of the invention thus makes ~~apodisation~~apodization easier.

Other artificial cladding gratings may be created from a variation of the cladding structure. By way of example, ~~figure~~Figure 5 shows a chirped type grating for which the pitch 30 of the section modulation of the cladding 17 evolves. The other elements of this figure are the same as those of figure 4 and have the same references.

It is also possible to combine the different examples of embodiments of the coupling element of the invention and create for example a grating that is both chirped and apodisedapodized.

5 It ~~is~~may be difficult to create apodisedapodized or chirped gratings by etching, especially for apodisationapodization which ~~requires~~may require good control, distributed along the length of the grating, ~~from~~of the cladding variation. The use of gratings created according to 10 the invention is particularly advantageousbeneficial.

15 Figure 6 shows diagrammatically ~~in~~a cross section of a coupling element ~~of the~~in accordance with an invention in which the modulation of the cladding structure is created by modulation of the position of the cladding with respect to the core.

Consequently, we can see on In this figure, the substrate 11 ~~in which~~includes a cladding 18 ~~is~~is created that is traversed by the core 12.

20 In this example, the section of the cladding is constant but its position in the cross section plane of the figure follows with respect to the axis x, a sinusoidal function of period Λ .

25 Of course, It will be appreciated that these different variantembodiments of the invention may be combined with one another.

The In an embodiment of the invention, the fabrication of the grating ~~of the invention~~ by modulation of the cladding structure permits a core with a constant section to be created. This ~~point~~ is of particular interest when the coupling element 30 is integrated into a more complex architecture. In this case ~~in fact~~, the coupling element is associated towith the rest of the component by creating simply the cladding in a zone of the substrate comprising the core, which permits the operation

of the component to be checked without the artificial cladding grating without having to make another mask for the part of the core that is ~~to be~~ associated ~~to~~ with the zone of interaction.

5 By way of example, figure 7 shows a coupling element that is ~~in fact~~ integrated into an optical architecture, in. In this example the architecture is an integrated optics coupler in a substrate 21.

10 ~~In this way, the~~ The coupler comprises in the substrate 21, two guide cores 24 and 25 which are close to one another in a coupling zone 26 in order to permit an energy exchange from one of the guides to the other and vice versa. The core 24 is associated among others after the coupling zone ~~to~~ with a coupling element 30 of the invention. This coupling element 15 is formed for example by a cladding 31 comprising a modulation of its section and by the part of the core 24 which traverses the cladding.

20 Thus, when a light wave penetrates the core 24 by one end 22, it is first ~~of all~~ split in the coupling zone into two parts, one part of the wave continues to be transported by the guide 24 ~~whilst~~ while the other part is transported by the core 25. The part of the wave transported by the core 24 is filtered by the coupling element 30 before leaving ~~by~~ the end 28 of the guide. The end 27 of the coupler directly transmits the part 25 of the wave coupled by the coupling zone in the core 25. ~~We consequently obtain at~~ At the output, a filtered signal and a reference signal may be obtained.

30 One application of the component of figure 7 may be for example a spectral detection system. In fact, if the coupling element 30 has a ~~wave length~~ wavelength linear response, the end 28 of the core 24 ~~can~~ may provide a signal that depends on the ~~wave length~~, wavelength, whereas ~~wavelength~~, while the end 27 provides a ~~standardisation~~ reference signal permitting the spectral

~~characterisation~~characterization for example of the position of a fine emission ray in the analysis spectrum.

This coupler may be ~~advantageously optimised~~optimized, before the coupling element 30 is created; this is especially 5 ~~advantageous~~may be used for balancing the two output ends 27 and 28.

Figures 8a to 8d show diagrammatically an example of an embodiment of a coupling element of the invention (for example 10 that of ~~figure~~Figure 2) using ion exchange technology and masks.

These figures are cross sections in a plane perpendicular to the surface of the substrate and perpendicular to the direction x of propagation.

Figure 8a shows the substrate 11 containing B ions. 15 A first mask 61 is created for example by photolithography on one of the faces of the substrate; this mask comprises an opening determined according to the dimensions (width, length) and the pattern of the cladding 13 that we wish to obtain. The mask 61 thus comprises the same modulations as those that we 20 ~~wish to create~~one desired in the cladding.

A first ionic exchange is ~~therefore~~ created between the A ions and the B ions contained in the substrate, in a zone of the substrate situated next to the opening of the mask 61. This exchange is obtained for example by soaking the substrate 25 equipped with the mask in a bath containing A ions and by possibly applying an electrical field between the face of the substrate on which the mask is located and the opposite face. The zone of the substrate in which this ionic exchange takes place forms the cladding 13.

30 To bury this cladding, an A ion re-diffusion ~~step is~~may be carried out with or without the use of an electrical field applied as previously described.

Figure 8b, shows the cladding after it has been partially buried. The mask 61 is generally removed before this step. partially burying the cladding.

5 The creation of the cladding of the invention is therefore similar to the creation of a guide core but with different dimensions.

10 The following step shown in figure 8c consists of forming. In Figure 8c, a new mask 65 is formed on the substrate for example by photolithography after possibly cleaning the face of the substrate on which it is created. This mask 15 comprises patterns capable of permitting the creation of configured to define the core 12.

A second ionic exchange is then created between the B ions of the substrate and the C ions which may or may not be the same as the A ions. This ionic exchange may take place as previously described by soaking the substrate in a bath containing C ions and by possibly applying an electrical field.

20 Finally, figure Figure 8d shows the component obtained after burying the core 12 obtained by re-diffusion of the C ions and final burying of the cladding, with the use or not of an electrical field. The mask 65 is generally removed before this burying step.

25 The conditions of the first and second ionic exchanges are defined in order to obtain the differences of refractive indices desired between the substrate, the cladding and the core. The adjustment parameters of these differences are in particular may be the exchange time, the temperature of the bath, the concentration in ions of the bath and the presence or absence of an electrical field.

30 As an example of an embodiment, the substrate 11 is made of glass containing Na^+ ions, the mask 61 is made of aluminium and has an opening of around 30 μm wide and a modulation on the opening of between a few and several dozen

micrometers (the length of the opening depends on the desired length of the cladding for the application in question).

The first ionic exchange ~~is~~may be carried out with a bath comprising Ag^+ ions at around 20% concentration, at a 5 temperature of around 330°C and for an exchange time of around 5 min. The cladding thus formed in the glass is then partially buried. This burying step is carried out by re-diffusion in a sodium bath at a temperature of around 260°C . The ~~length~~duration of ~~this step~~the re-diffusion depends on the 10 depth of burying desired for the final component. In this way, for a surface component a duration of around 3 minutes ~~is~~may be sufficient whereas for a buried component a duration of around 20 minutes ~~will~~may be selected. In this second case, it ~~is also necessary~~may be desirable to carry out the burying 15 of the cladding under an electrical field before the second exchange. In this way, a current of 20 mA ~~is~~may be applied between two sodium baths on either side of the plate at a temperature of 260°C for 10 minutes.

The mask 65 ~~is~~may also be made of aluminiumaluminum and 20 has a pattern opening of around 3 μm wide (the length of the pattern depends on the desired length of the core for the application in question).

The second ionic exchange ~~is~~may be carried out with a bath also comprising Ag^+ ions at around 20% concentration, at a 25 temperature of around 330°C and for an exchange time of around 5 min. Then the core thus formed is partially buried in the glass by re-diffusion in a sodium bath at a temperature of around 260°C for 3 min. For a buried component, this step ~~is~~re-diffusion may not be necessary.

30 The final burying of the cladding and the core ~~takes~~may take place under an electrical field, with the two opposite faces of the substrate in contact with two baths (in this example sodium) capable of permitting a difference in

potential to be applied between these two baths. For a surface component, a duration of less than one minute ~~is may be~~ sufficient, in the case of a buried component a duration of around 30 minutes ~~is may be~~ used, with the burying being carried 5 out with a current of 20 mA at 240°C.

Many variants of the previously described process may be created. In particular, the burying steps of the cladding and the core may be carried out as previously described during 2 successive steps but they may also be carried out 10 simultaneously in certain cases, with the core having an ionic concentration higher than that of the cladding, it is buried quicker than the cladding, which permits among others to centre the core in the cladding.

The difference in concentration between the core and the 15 cladding is generally obtained either by re-diffusion in a bath of ions forming the cladding or by a difference in concentration of the ions introduced in ~~steps~~acts a) and b).

As we have already seen, to bury the cladding and the core, a variant of the process consists of depositing on the 20 substrate 11, a layer of material 68, shown in dotted lines in ~~figure~~Figure 8d. In order to make optical guiding possible, it is desirable that this material must advantageously have a refractive index lower than that of the cladding.

Moreover, in this example, the cladding is created before 25 the core, but it ~~is of course~~may be possible to create the core before the cladding.

The fabrication of the component of the invention is not restricted to the technique of ion exchange. The component of the invention may also be created by any techniques which 30 permit the refractive index of the substrate to be modified.

Furthermore, as we have already seen, the period, size and position of the grating created, with respect to the core

and the cladding, are parameters which can be adapted to suit the applications.

Figures 9a and 9b show in a perspective view a variant of an embodiment of a coupling element of the invention that 5 does not use masks.

Thus ~~figure~~ Figure 9a shows the substrate 11 in which a cladding 60 with a uniform structure has been created beforehand, for example, by masking and ion exchange. ~~localised~~ Local heating 63 of the cladding ~~is~~ may then be 10 created ~~by means of~~ using a laser beam 71 (for example a CO₂ type laser) aimed at the substrate. This beam is moved along the cladding, by intervals corresponding to the desired period of the grating. The ~~localised~~local heating produces re-diffusion 15 of the ions in the cladding, which results in both a change in section and index. The grating R is thus created in the cladding.

After this step (~~figure~~Figure 9b), a guide 75 is fabricated in the cladding for example also by masking and ion exchange in order to obtain the coupling element of the 20 invention.

In this example of the embodiment, the modulations of the cladding structure are obtained without modulating the cladding mask pattern. It is therefore possible to modify the opto-geometrical distribution of the cladding by simply 25 creating periodic or pseudo-periodic ~~localised~~localized heating. This heating can be obtained by all means permitting part of the substrate to be heated locally on a zone around the size of the desired grating period, following the direction of propagation of the modes. ~~The~~ ~~se~~ ~~means~~ ~~may~~ ~~be~~ ~~for~~ ~~example~~ 30 ~~laser~~ Laser exposure or ~~the~~ ~~use~~ ~~of~~ an electrical arc may ~~be~~ used.

The exposure of the cladding to a laser beam may also be made after the guide core has been created.

Figures 10a and 10b show diagrammatically examples of embodiments of the masks M1 and M2 permitting a cladding with section modulation to be obtained.

These figures are elevation views of the masks and only 5 show the part of the masks permitting the grating to be obtained. The white zones of the mask patterns correspond to the openings of the masks.

These masks permit a periodic grating of period Λ to be obtained by variation of the width of the patterns.

REFERENCE

- [1]: C.Y. Lin and L.A. Wang, "Less tunable long period fibre grating made from etched corrugation structure", Electron. Lett., 35 (21), (1999), pp 1872-1873.

ABSTRACT OF THE DISCLOSUREINTEGRATED OPTICS COUPLING ELEMENT COMPRISING A GRATING
CREATED IN A CLADDING AND ITS FABRICATION METHOD

The invention relates to an integrated optics coupling element ~~characterised in that it comprises in~~ ~~includes~~ a substrate (11), an optical guide core (12), an optical cladding (13) independent of the core and surrounding at least one portion of the core in a zone of the substrate called the zone of interaction, ~~in which the.~~ The cladding has at least in the zone of interaction a modulation of its structure so as to form a grating (R), ~~in which the.~~ The refractive index of the cladding is different from the refractive index of the substrate and lower than the refractive index of the core at least in the part of the cladding next to the core in the zone of interaction.

~~The Embodiments of the invention has applications in particular for the fabrication of~~ ~~may be used to make~~ gain flatteners for optical amplifiers or even for the fabrication of ~~to make~~ linear response filters whose wavelength ~~wavelength~~ is on a spectral band.